EG&G Idaho, Inc
FORM EG&G-2631 (Rev. 12-88)

Project File Number ____________
EDF Serial Number ERP-BWP-69
Functional File Number ____________

ENGINEERING DESIGN FILE

Project/Task Pit 9 Comprehensive Demonstration

Subtask Baseline Risk Assessment

EDF Page 1 of 1

Subject : Pit 9 Residual Risk Assessment

Abstract: This document reports the residual human health risks from transuranic contaminants following remediation of Pit 9.

Distribution (complete package) I. del C. Figueroa, J. J. King, D. L. Forsberg Y. McClellan, J. M. McCarthy

Distribution (cover sheet only): Project EDF file log, EDF serial no. log R. L. Nitschke, F. P. Hughes, W. C. Craft, M. D. McKenzie, R. L. Norland

Author	Dept.	Reviewed	Date	Approved	Date
I. del C. Figueroa Inés del C. Figueroa	7830	V. W. Watson V. W. Watson	3/17/92	F. P. Hughes FPHughes	3/18/92
J. J. King John J. King	7830			W. H. Sullivan W H Sullivan Br RLN	3/18/92
J. M. McCarthy James M. McCarthy	7830				
Y. McClellan Yvonne McClellan	7830				

PIT 9 RESIDUAL RISK ASSESSMENT

J. J. King
I. del C. Figueroa
J. M. McCarthy
Y. McClellan

PIT 9 RESIDUAL RISK ASSESSMENT

1. INTRODUCTION

This document reports the residual human-health risks from transuranic contaminants following remediation of Pit 9. Pit 9 is located within the Subsurface Disposal Area (SDA) of the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL). This report includes the guidelines and assumptions for conducting the residual risk assessment (RRA) and the methodology for the inventory determination, surface and groundwater modeling, and the human health risk evaluation. Modeling and risk results are presented and briefly discussed.

2. GUIDELINES AND ASSUMPTIONS

Listed below are the guidelines and assumptions that were used for defining the modeling approach and methodology for the Pit 9 RRA:

1. A residual transuranic inventory of 10 nCi/g for treated waste materials will be returned to Pit 9 following remediation. No other contaminants were considered in the RRA.
2. The inventory will be assumed to be distributed uniformly throughout the residual waste volume of Pit 9. The fate-and-transport modeling will start in 1992 with a clean fill (overburden) of soil with characteristics similar to soils at the Subsurface Disposal Area (SDA).
3. It is assumed that Pit 9 will be backfilled to surface grade with 2.1 m (7 feet) of clean soil. This depth is based on the following. The remediation process for Pit 9 is assumed to be 90% efficient which means that 90% of the original waste volume and soil will be returned to Pit 9. Assuming that the remediation will process 10 feet of material (8 feet of waste and 2 feet of underburden), the residual material returned to the pit will be 9 feet high. This will add 1 foot of fill to the existing 6-foot overburden.
4. A hundred years of institutional control from 1992 will be assumed. During this period, an industrial scenario will be evaluated. In the

year 2091, when Pit 9 is free of institutional control, a residential scenario will be evaluated. Risks will be evaluated for receptors located at the boundary of Pit 9 and at 400 m to the south at the southern boundary of WAG-7 for both institutional control and residential scenarios.

5. The fate-and-transport calculations will proceed 1000 years from 1992 (the effective year for reduced waste re-emplacement in Pit 9). Two time periods will be evaluated: 1992-2091 and 2091-2991. The risk evaluation will use a moving 25-year time window for the industrial scenario (1992-2091) and a moving 30-year time window for the residential scenario (2091-2991). The maximum risk value for all contaminants for the applicable pathways will be determined for the appropriate time window. Calculated values will be averaged for the 25-year and 30-year moving time windows when evaluating the maximum aggregate-risk time windows. Peak contaminant concentrations will not be used for any risk evaluations.
6. Only human receptors will be addressed; no ecological assessment will be performed. Five major exposure pathways will be evaluated: external exposure, ingestion of soil, ingestion of food crops, inhalation of soil-contaminated air, and ingestion of groundwater.
7. The contaminants returned to Pit 9 will be assumed to be uncontained. A compartmentalized computer model will be used to calculate the transport of contaminants via biota to the surface of the Pit 9. The Pit 9 ground surface will be treated as a soil deposition zone with a net deposition rate of 7E-03 cm/y. This number is based upon a maximum of 7 m of soil emplaced since the last lava flows occurred under the SDA (approximately 100,000 years ago).
8. The groundwater fate-and-transport modeling will assume that contaminants within the waste matrix of Pit 9 are accessible to infiltration of moisture and removal by leaching. The groundwater modeling will be performed using the Track 1 groundwater model (GWSCREEN). The groundwater modeling will assume a steady-state infiltration rate of 10 cm/yr, based upon measurements performed in the Spring of 1989 near Pit 9. The sensitivity of the contaminant concentrations to the infiltration rate will be demonstrated using

annual rates of 5 cm/yr and 20 cm/yr. The effects of flooding will be discussed qualitatively. Baseline calculations will include the pertinent contaminants using the best known nominal hydrologic parameters.

3. INVENTORY DETERMINATION

This RRA assumes a 10 nCi/g concentration for the transuranic radionuclides. The list of candidate transuranic radionuclides for Pit 9 includes Pu-238, Pu-239, Pu-240, Pu-242, and Am-241. Pu-241 is a precursor to Am-241 but it is not categorized as a direct component of transuranic (TRU) waste. Pu-241 is not an alpha emitter, and its half-life is less than 20 years (Pu-241 half-life = 14.35 years).

The method for determining the transuranic constituents of the 10 nCi/g soil-waste matrix returned to Pit 9 was derived from the ratios of the 1992 Pit 9 activities for the 5 radionuclides noted above. Table 1 displays the activities in curies for 1992 based upon the Engineering Design File by King[1].

The fraction of the total activity was determined for each radionuclide. This fractional breakdown was then assumed for the 10 nCi/g soil-waste matrix. A 10 nCi/g concentration equals the total activity in the soil-waste matrix returned to Pit 9, divided by the total mass of that matrix. If 2.74 m (9 feet) of matrix is returned to Pit 9, and Pit 9 has an area of 3.98E+3 m^2, then the volume of this material is 1.09E+4 m^3. Assuming a density of 1.5E+06 g/m^3, the total mass is 1.64E+10 g. Multiplying this number by 10 nCi/g produces a total transuranic activity of 164 Ci. Using the 1992 fractional activity shown in Table 1, the activity for each radionuclide is then calculated and also displayed in Table 1. These values represent the residual transuranic inventory for Pit 9.

Table 1. Pit 9 radionuclide activities for 10 nCi/g transuranic waste.

Radionuclide	Half-Life (y)	Pit 9 1992 Activity (Ci)	Fraction of Total Activity	Activity For 10 nCi/g Waste (Ci)
Pu-238	8.774E+01	2.55E+01	6.871E-03	1.127E+00
Pu-239	2.412E+04	1.160E+03	3.126E-01	5.127E+01
Pu-240	6.570E+03	2.65E+02	7.141E-02	1.171E+01
Pu-242	3.763E+05	1.26E-02	3.395E-06	5.568E-04
Am-241	4.322E+02	2.260E+03	6.090E-01	9.988E+01
Total		3.711E+03	1.00E+00	1.64E+02

4. PIT 9 SURFACE MODELING METHODOLOGY AND MEDIA CONCENTRATIONS

Following remediation of Pit 9, it was assumed that the Pit 9 was filled to surface grade by placing 2.1 m (7 feet) of clean soil over the treated material. Populations of small mammals and plants were assumed to be present at Pit 9 after remediation. A biotic transport model, DOSTOMAN[2], was used to mathematically simulate the movement of radionuclides by plant uptake and animal excavation. The physical model consists of four 52.5-cm thick soil compartments that overlay the soil-waste matrix in Pit 9.

Three plant species (Russian thistle, crested wheatgrass, and sagebrush) and four rodent species (Townsend ground squirrels, Ord's kangaroo rats, deer mice, and montane voles) were considered in the biotic transport model. The 2.1-m overburden prevents mammal intrusion and limits root growth into the waste. Sagebrush is the only plant species whose roots have the potential to grow deep enough to interact with the waste. Table 2 displays the maximum depth assigned to each mammal and plant species used in the DOSTOMAN code for the RRA surface modeling.

Table 2. Maximum depth for mammals and plant species included in the DOSTOMAN surface modeling for Pit 9.

Mammal	Maximum Depth (cm)	Plant	Maximum Depth (cm)
Townsend Ground Squirrel	200[a]	Russian Thistle	180[c]
Ord's Kangaroo Rat	90[b]	Crested Wheatgrass	150[d]
Deer Mouse	50[b]	Sagebrush	225[d]
Montane Vole	60[b]		

a. McKenzie et al., 1982.[3]
b. Reynolds and Laundre, 1988.[4]
c. Klepper et al., 1985.[5]
d. Reynolds and Fraley, 1985.[6]

During institutional control (1992-2091), appropriate populations of Russian thistle and crested wheatgrass were assumed to revegetate at Pit 9. Sagebrush was not modeled during the institutional control period because currently it is not present at Pit 9. Current procedures for the SDA, requiring surface soil maintenance, prevent the growth of sagebrush.[7] It is assumed that the institutional control will continue to provide maintenance of Pit 9 surface soil. Estimated populations of Townsend ground squirrels, Ord's kangaroo rats, deer mice, and montane voles were also assumed to inhabit Pit 9 after remediation, based on studies at the RWMC and surrounding areas. The maximum burrowing depth for mammals and the maximum vertical root depth for the two evaluated plants during the institutional control period prevented intrusion into the waste matrix.

Following institutional control (2091-2991), the surface modeling allows revegetation of sagebrush at Pit 9. The density of small mammals was adjusted for a plant community that includes Russian thistle, crested wheatgrass, and sagebrush. Mammal populations during post-institutional control also include the Townsend ground squirrel, Ord's kangaroo rat, deer mice, and montane voles.

Movement of radionuclides between the contaminated compartment of Pit 9 and the four overburden compartments is accomplished with biotic transport rate constants. For plants, these constants are based upon such variables as the fraction of biomass above ground, the total biomass for each species, the fractional root distribution in each compartment, the plant uptake of each radionuclide, and the annual death rate for each plant species. For the mammals, the rate constants depend upon the fractional distribution of burrows in each compartment, the mass of soil moved to the surface by each species, the fraction of new burrows per year for each species, and the number of individuals for each species.

The DOSTOMAN code transports the radionuclides from the contaminated "source" compartment to the "sink" compartments by means of solving a system of linear differential equations at specified time steps. Soil concentrations of radionuclides in the surface compartment are determined primarily by the death and accumulation of decaying plant biomass, and direct transport of contaminated soil to the surface by burrowing mammals. The 2.1-m overburden at Pit 9 prevents direct burrowing of any mammals beyond the overburden (see Table 2). Sagebrush is the only plant species whose roots may grow and interact with the soil-waste matrix at Pit 9. This will occur only during the post-institutional control period when sagebrush is allowed to revegetate at Pit 9. Hence, during the institutional control period, the surface overburden will not be contaminated with transuranic radionuclides via biotic transport.

Calculations with DOSTOMAN were performed from 1992 to 2991 (1000 years beyond the present). A maximum surface 30-year risk window was identified for the time period of 716 to 745 years after 1992 (2707-2736). Table 3 displays the average soil concentrations in units of Ci/g at the operable unit boundary for the 716-745 residential time window. The average soil concentration was multiplied by 4.2E-5 g/m^3 (the airborne particulate concentrations at the 95% confidence level for 10 micron or smaller particles measured at Pit 9 during 1990)[8] to produce the Pit 9 operable unit boundary air concentration shown in Table 3.

The second column in Table 3 displays the air concentration for each radionuclide at the WAG-7 boundary, 400 m south of Pit 9. This value is determined by multiplying the Pit 9 boundary air concentration by 361 m^3/s (the average volumetric air flow at Pit 9 for a height of 2 m) to produce the airborne radionuclide release rate in Ci/s. An analytical expression from Hanna et al.[9], for distances greater than 100 m, was used to disperse a release at Pit 9. This equation incorporated measured atmospheric parameters at the INEL. The resultant dispersion factor (3.03E-5) was multiplied by the radionuclide release rate to produce the concentration for radioactive-contaminated airborne particles with a diameter of 10 microns or less.

Table 3 also lists the radionuclide soil concentrations at the WAG-7 boundary for an assumed soil depth of 10 cm. This value is derived from expected fallout rates for 10-micron particles and is then integrated conservatively for 745 years. Even with this assumed steady-state rate for 745 years, the soil concentration of radionuclides at the WAG-7 boundary is 2900 times less than the "source" soil at Pit 9. If minimal human health risk is found for the Pit 9 operable boundary, the risk at the WAG-7 boundary will be negligible. The values shown in Table 3 represent the surface media concentrations that were evaluated in the RRA.

Table 3. Soil and air concentrations at the Pit 9 boundary and WAG-7 boundary.

Nuclide	Pit 9 boundary		WAG-7 boundary	
	Soil Concentration (Ci/g)	Air Concentration (Ci/m^3)	Soil Concentration (Ci/g)	Air Concentration (Ci/m^3)
Pu-238	1.27E-19	5.31E-24	4.38E-23	5.82E-26
Pu-239	1.79E-15	7.53E-20	6.20E-19	8.24E-22
Pu-240	3.87E-16	1.62E-20	1.34E-19	1.78E-22
Pu-242	1.98E-20	8.33E-25	6.86E-24	9.12E-27
Am-241	1.41E-14	5.93E-19	4.88E-18	6.49E-21

5. PIT 9 GROUNDWATER MODELING METHODOLOGY AND RESULTS

The groundwater pathway was evaluated for plutonium and americium. Both contaminants are relatively insoluble, and the subsequent calculations will demonstrate that these radionuclides will not reach the groundwater in the 1000-year time frame considered in the RRA. The following analysis shows the methodology used to calculate travel times to the aquifer.

Assuming advective transport, the contaminant travel time to the groundwater (T_c) can be calculated from the following equations:

$$T_c = T_w * R_d \tag{1}$$
$$T_w = D / V_w \tag{2}$$
$$V_w = I/\theta \tag{3}$$
$$R_d = 1 + (\rho_b * K_d)/\theta \tag{4}$$

where

T_c	=	travel time of the contaminant (y)
T_w	=	travel time of water (y)
R_d	=	contaminant retardation due to adsorption (assumes equilibrium sorption)
D	=	distance through the unsaturated zone to the aquifer (m)
V_w	=	water velocity (m/y)
I	=	infiltration rate (m/y)
θ	=	moisture content
ρ_b	=	bulk density (g/ml)
K_d	=	partition coefficient between soil and water (ml/g)

For this analysis, it is assumed that the entire unsaturated zone is basalt, with the following parameter values:

I	=	0.1 m/y
ρ_b	=	2.5 g/ml
θ	=	0.06
D	=	176 m

Substitution of these parameter values shows that:

$$V_w = 1.67 \text{ m/y}$$
$$T_w = 105.6 \text{ y}$$

Travel times for plutonium and americium are given in Table 4. The estimated travel time to the groundwater is 9.69E+04 years for plutonium. The estimated travel time to the groundwater is 1.50E+06 years for americium.

Table 4. Estimated contaminant travel times from Pit 9 to the Snake River Plain aquifer.

Radionuclide	K_d[a] (ml/g)	R_d	T_c (y)
Plutonium	22	9.18E+02	9.69E+04
Americium	340	1.42E+04	1.50E+06

a. K_d values are obtained from the Track 1 Guidance document[10]. These K_d values are assumed to be conservative.

Since travel times are strongly affected by the assumed distribution coefficients and infiltration rates, additional analyses were performed to show the sensitivity for these parameters (see Table 5). For an infiltration rate of 0.1 m/y, a distribution coefficient of 0.2 ml/g would be required for radionuclides to reach the aquifer in less than 1000 years. Since both plutonium and americium are quite insoluble, therefore it is not reasonable to justify a distribution coefficient small enough for them to reach the aquifer in 1000 years.

The other variable strongly influencing the travel times of the radionuclides is the infiltration rate. Additional sensitivity analyses were performed to evaluate the effect of infiltration rate, using the established Track 1 K_d values shown in Table 4. For americium, having a K_d of 340 ml/g, an infiltration rate of 150 m/y would be required to reach the aquifer in 1000 years. An infiltration rate of 10 m/y would be required for plutonium (K_d = 22 ml/g) to reach the aquifer in 1000 years. The probability of floods equalling these annual infiltration rates (10 m/y or 150 m/y) on an annual basis is not credible.

The results indicate that, using reasonable distribution coefficients and infiltration rates, plutonium and americium will not reach the aquifer during the evaluated time period (1000 years).

Table 5. Sensitivity of contaminant travel times to distribution coefficient (K_d) and infiltration rate (I).

I (m/y)	θ^a	T_w (y)	K_d (ml/g)	R_d	T_c (y)
0.1	0.06	105.6	340	1.42E+04	1.50E+06
0.1	0.06	105.6	22	9.18E+02	9.69E+04
0.1	0.06	105.6	2	8.43E+01	8.91E+03
0.1	0.06	105.6	0.2	9.33E+00	9.86E+02
Americium					
0.05	0.05	176.0	340	1.70E+04	2.99E+06
0.2	0.08	70.4	340	1.06E+04	7.48E+05
150	0.22	0.3	340	3.86E+03	9.98E+02
Plutonium					
0.05	0.05	176.0	22	1.10E+03	1.94E+05
0.2	0.08	70.4	22	6.89E+02	4.85E+04
10	0.15	2.6	22	3.68E+02	9.71E+02

a. Moisture content values from the van Genuchten curves presented in Baca, et. al.[11].

6. RISK EVALUATION

The purpose of this risk evaluation was to determine potential risks associated with the residual inventory at Pit 9, following waste treatment and remediation. The proposed remedial alternatives for Pit 9 require that the treated material returning to Pit 9 after remediation would contain less than 10 nCi/g for transuranic radionuclides.

The residual risk assessment used a specified residual inventory in Pit 9 of 10 nCi/g, including Pu-238, Pu-239, Pu-240, Pu-242, and Am-241 (see Table 1). Potential risks to human receptors were quantified for the selected radionuclides of concern for multiple exposure pathways under future exposure scenarios. The risk assessment described in this section includes three main steps: exposure assessment, toxicity assessment, and risk characterization.

6.1 Exposure Assessment

The risk assessment assumed that institutional control will continue at Pit 9 for a period of 100 years from 1992. Two exposure scenarios were evaluated: an industrial scenario during the institutional control period (1992-2091) and a residential scenario after institutional control (2091-2991). The residential scenario was evaluated for a period of 900 years after institutional control.

Hypothetical receptors were located at the boundary of Pit 9 and at 400 m to the south at the southern boundary of WAG-7 for both industrial and residential scenarios. Five potential exposure pathways were evaluated, as applicable to the exposure scenario: ingestion of soil, inhalation of soil-contaminated air, ingestion of groundwater, ingestion of food crops (for residential scenario only), and external exposure.

The objective of the exposure assessment is to estimate the magnitude of exposure to the radionuclides of concern at Pit 9. The magnitude of exposure is determined by estimating the quantity of the contaminant available for contact at the exposure medium and location during a specified time period. For the residual risk assessment, media concentrations for surface soil and air were estimated using biotic transport modeling. Groundwater concentrations were assumed to be zero because the groundwater modeling indicated that the radionuclides will not reach the aquifer during the evaluated time period (1000 years). Media concentrations (soil and air) used in the residual risk evaluation were shown in Table 3.

To evaluate the ingestion of food crops pathway, concentrations in vegetation were estimated from the surface soil concentrations shown in Table 3. The crops were assumed to be located at the edge of Pit 9 or at the southern boundary of WAG-7. Uptake of radionuclides by plants was calculated using the soil-to-plant bioconcentration factor, B_v. B_v is defined as the ratio of the concentration of the contaminant in vegetation to the concentration in soil. B_v values for the radionuclides of concern at Pit 9 were obtained from Baes et al.[12] The following relationship was used to estimate the concentration in food crops for the five evaluated radionuclides:

$$C_v = C_s * B_v \qquad (5)$$

where

C_v = concentration in vegetation (pCi/g)
C_s = concentration in soil (pCi/g)
B_v = soil-to-plant bioconcentration factor (from Reference 12)

The B_v values and the resulting concentration in vegetation for each radionuclide are shown in Table 6.

The methods used to evaluate human exposure to the radionuclides of concern followed EPA guidance.[13,14] Exposure parameters were obtained from the "Standard Default Exposure Factors"[15] guidance and EPA Region 10 guidance.[16] The exposure parameters used in the residual risk assessment are shown in Table 7. The evaluation of ingestion of soil considered both child (0 to 6 years) and adult exposures following EPA guidance (see Reference 14).

Table 6. Estimated concentrations of radionuclides in food crops and B_v values used.

Radionuclide	B_v[a]	Concentration in food crops (pCi/g)	
		Pit 9 boundary	WAG-7 boundary
Pu-238	4.50E-04	5.72E-11	1.97E-14
Pu-239	4.50E-04	8.06E-07	2.79E-10
Pu-240	4.50E-04	1.74E-07	6.03E-11
Pu-242	4.50E-04	8.91E-12	3.09E-15
Am-241	5.50E-03	7.76E-05	2.68E-08

a. All B_v values obtained from Baes et al. (see Reference 12).

Table 7. Exposure parameters used in the residual risk assessment of Pit 9.

Exposure pathway	Exposure scenario	Intake rate[a]	Exposure frequency (d/y)	Exposure duration (y)
Ingestion of soil	Industrial	50 mg/d	250	25
	Residential	200 mg/d (child, 0-6) 100 mg/d (adult)	350 350	6 24
Inhalation	Industrial	20 m^3/d	250	25
	Residential	20 m^3/d	350	30
Ingestion of water	Industrial	1 L/d	250	25
	Residential	2 L/d	350	30
Ingestion of food crops	Industrial	N/A	N/A	N/A
	Residential	8.62 g/d[b]	350	30
External exposure	Industrial	N/A	250	25
	Residential	N/A	350	30

N/A means that the parameter is not applicable to the exposure pathway or scenario.

a. Intake rate values obtained from EPA "Standard Default Exposure Factors," (see Reference 15) unless otherwise noted.

b. Intake rate of food crops obtained from EPA region 10 guidance (see Reference 16); intake rate includes ingestion of fruits, vegetables, and root crops.

6.2 Toxicity Assessment

All the radionuclides are classified by the EPA as human carcinogens (Group A carcinogens). Slope factors (SFs) are used to evaluate the carcinogenic risk potential of radionuclides. A toxicity assessment was conducted to identify the SFs for the radionuclides. The SFs used in this evaluation were obtained from HEAST.[17] SFs for radionuclides represent best-estimate values for lifetime cancer incidence risk per unit exposure. The SFs used in this evaluation are shown in Table 8.

Table 8. Slope factors for radionuclides evaluated in the residual risk assessment of Pit 9.[a]

Radionuclide	Ingestion SF $(pCi)^{-1}$	Inhalation SF $(pCi)^{-1}$	External Exposure (SF) $(y/pCi/m^2)^{-1}$
Pu-238	2.8E-10	4.2E-08	6.1E-14
Pu-239	3.1E-10	4.1E-08	2.6E-14
Pu-240	3.1E-10	4.1E-08	5.9E-14
Pu-242	3.0E-10	3.9E-08	4.9E-14
Am-241	3.1E-10	4.0E-08	1.6E-12

a. All SFs were obtained from 1991 HEAST (see Reference 17). The SFs for radionuclides are currently being revised by the EPA; the revision will result in lower risks than the ones calculated with the above SFs (Personal communication with A. Wolbarst, U. S. Environmental Protection Agency).[18]

The SFs presented in Table 8 were used in the calculation of cancer risks for each exposure pathway, using specific exposure parameters for each scenario. Unit risk (UR) values were calculated for each exposure pathway as follows:

For ingestion and inhalation:

$$UR = SF * IR * EF * ED \qquad (6)$$

For external exposure:

$$UR = SF * \text{soil depth} * \text{soil density} * ED \quad (7)$$

where

UR	=	unit risk (pathway-specific)
SF	=	slope factor (pathway-specific, see Table 8)
Soil depth	=	soil depth (0.1 m)
Soil density	=	soil density (1.5E+06 g/m^3)
IR	=	intake rate (pathway-specific, see Table 7)
EF	=	exposure frequency (see Table 7)
ED	=	exposure duration (see Table 7)

For the calculation of UR for the external exposure pathway, the exposure duration (ED) parameter was adjusted relative to the exposure frequency (EF), because the receptor was assumed to be exposed fewer than 365 days per year. For the industrial scenario, the ED was multiplied by 0.68 (250 d/365 d). For the residential receptor, the ED was multiplied by 0.96 (350 d/365 d).

The calculated pathway-specific UR values used in the calculation of residual risks are shown in Appendix A.

6.3 Risk characterization

The potential for carcinogenic effects was evaluated by calculating the cancer risk from radionuclides assumed to be present in Pit 9 after remediation, based on a residual inventory of 10 nCi/g. The calculated risks represent the incremental probability of an individual developing cancer over a lifetime, as a result of exposure to the radionuclides.

Cancer risks were calculated by comparing the concentration of the radionuclide in the medium of concern (soil, air, water, or food crops) to the appropriate pathway-specific unit risk value, as follows:

$$R = C * UR \quad (8)$$

where

R	=	cancer risk, expressed as a unitless probability
C	=	concentration of the radionuclide (pathway-specific)
UR	=	unit risk (pathway-specific)

To assess the overall potential for carcinogenic effects from exposure to multiple radionuclides, the individual cancer risks were added to obtain the total pathway risk. Cancer risk results for individual and multiple radionuclides for each exposure pathway and scenario are shown in Appendix A.

7. RESULTS OF RESIDUAL RISK ASSESSMENT FOR PIT 9

This evaluation quantified potential residual risks associated with treated waste that will be returned to Pit 9 after remediation. The treated material was assumed to contain 10 nCi/g of five transuranic radionuclides: Pu-238, Pu-239, Pu-240, Pu-242, and Am-241. It was also assumed that the pit was backfilled to surface grade with the treated material covered with 2.1 m (7 feet) of clean soil. Residual risks were calculated for future receptors including both industrial and residential scenarios. Cancer risks were quantified following EPA guidance.

A summary of the risk results for the Pit 9 residual risk assessment is shown in Table 9. Pathway risks were added to obtain the total risk (from multiple radionuclides and multiple pathways). The resulting cancer risk were compared to the acceptable National Contingency Plan (NCP)[19] target risk range for remediation of 1.0E-04 to 1.0E-06.

Modeling of radionuclide transport to the aquifer indicated that radionuclides from Pit 9 will not migrate to the groundwater during the evaluated time period (1000 years). As a result, there are no risks from potential ingestion of groundwater to future receptors (industrial or residential).

The biotic transport model indicated that during the institutional control period there is no interaction between plants or burrowing animals with the residual waste at Pit 9. During the institutional control period, the cover at Pit 9 will be maintained and sage brush (the only plant species able to interact with the waste) will not be allowed to inhabit Pit 9. Due to the lack of biotic transport pathways, no surface contamination occurs during the institutional control period, resulting in no risks for industrial receptors at the Pit 9 or WAG-7 boundary.

After 100 years, Pit 9 is assumed to be free from institutional control and a residential scenario was evaluated at both locations (Pit 9 and WAG-7 boundary). Because of the end of institutional control and the presence of plants and burrowing animals, biotic transport pathways are possible and surface contamination is allowed to occur at Pit 9 after 100 years. Although the biotic transport modeling provided a mechanism for the movement of waste to the surface of Pit 9, the estimated surface concentrations were very low, resulting in very low risks for residential receptors. The evaluation of the residential scenario indicated that cancer risks are below the range (1.0E-04 to 1.0E-06) of acceptable risk for carcinogens. The total cancer risk for a residential receptor was 1.1E-07 at the Pit 9 boundary and 1.0E-10 at the WAG-7 boundary (see Table 9).

The risk results indicate that the remediation limit of 10 nCi/g represents an acceptable cancer risk to future industrial or residential receptors. Because the evaluation was based on reasonable modeling assumptions and conservative exposure parameters, the 10 nCi/g level should be protective of human health.

Table 9. Summary of cancer risk results for the Pit 9 residual risk assessment of 10 nCi/g of treated waste containing Pu-238, Pu-239, Pu-240, Pu-242, and Am-241.

PIT 9 RESIDUAL RISK ASSESSMENT RESULTS[a] RISK CHARACTERIZATION FOR 10 nCi/g (Pu-238, Pu-239, Pu-240, Pu-242, and Am-241)			
Scenario	Exposure Pathway	Cancer Risk	
		PIT 9 Boundary	WAG-7 Boundary
Institutional Control Period (Industrial)	Soil ingestion	0	0
	Inhalation	0	0
	Ingestion of groundwater	0	0
	External exposure	0	0
	Total	0	0
Post-institutional Control Period (Residential)	Soil ingestion	6.4E-09	2.2E-12
	Inhalation	5.8E-09	6.3E-11
	Ingestion of groundwater	0	0
	Ingestion of food crops	2.2E-09	7.6E-13
	External exposure	9.8E-08	3.4E-11
	Total	1.1E-07	1.0E-10

a. The toxicity values used in the calculation of residual risks were obtained from the EPA 1991 HEAST (see Reference 17). The toxicity values are currently being revised by the EPA; the revision will result in lower risks than the ones presented above [Personal communication with the Office of Radiation Programs (see Reference 18)].

8. REFERENCES

1. J. J. King, "Methodology for Determination of a Radiological Inventory for Pit 9 and Corresponding Results", Engineering Design File ERP-BWP-64, July 7, 1991.

2. R. W. Root, Jr., *Documentation and User's Guide for "DOSTOMAN"--A Pathways Computer Model of Contaminant Transport*, Savannah River Laboratory, 1981, DPST-81-549.

3. D. H. McKenzie, L. L. Cadwell, L. E. Eberhardt, W. E. Kennedy, R. A. Peloquin, and M. A. Simmons, *Relevance of Biotic Pathways to the Long-Term Regulation of Nuclear Waste Disposal*, Volume 2, NUREG/CR-2675, PNL-4241, 1982.

4. T. D. Reynolds and J. W. Laundre, "Vertical Distribution of Soil Removed by Four Species of Burrowing Rodents in Disturbed and Undisturbed Soils," *Health Physics*, Volume 54 (no. 4), 1988.

5. E. L. Klepper, K. A. Gano, and L. L. Cadwell, *Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site*, PNL-5247, 1985.

6. T. D. Reynolds and L. Fraley, "Root Profiles of Some Native and Exotic Plant Species in Southeastern Idaho," *Environmental and Experimental Botany*, Volume 29 (No. 2), 1989.

7. RWMC/SWEPP Programs Project Directive, "RWMC Operations in the Subsurface Disposal Area," PD-RS-2.2, July 17, 1991.

8. Personal communication with J. W. Tkachyk, Environmental Monitoring Unit, EG&G Idaho, Inc.

9. S. R. Hanna, G. A. Briggs and R. P. Hosker, Jr., *Handbook on Atmospheric Diffusion*, Technical Information Center, U. S. Dept. of Energy, DOE/TIC-11223, Springfield, Virginia, 1982.

10. Idaho National Engineering Laboratory, *Track 1 Sites: Guidance for Assessing Low Probability Hazard Sites at INEL*, U. S. Department of Energy Field Office, Idaho, DOE/ID-10340(91), October 1991.

11. R. G. Baca, S. O. Magnuson, H. D. Nguyen and P. Martin, *A Modeling Study of Water Flow in the Vadose Zone Beneath the Radioactive Waste Management Complex*, Idaho National Engineering Laboratory, EG&G Idaho Inc., EGG-GEO-10068, January 1992.

12. C. F. Baes, R. D. Sharp, A. L. Sjoreen, and R. W. Shor, *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, prepared by Oak Ridge National Laboratory for the U. S. Department of Energy, ORNL-5786, September 1984.

13. U. S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual*, EPA/540/1-89/002, December 1989.

14. U. S. Environmental Protection Agency, *EPA Region 10 Supplemental Risk Assessment Guidance for Superfund*, August 16, 1991.

15. U. S. Environmental Protection Agency, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Supplemental Guidance*, Interim Final, "Standard Default Exposure Factors," OSWER Directive 9285.6-03, March 25, 1991.

16. U. S. Environmental Protection Agency, *Region 10 Statement of Work RI/FS Risk Assessment Deliverables*, January 1990.

17. U. S. Environmental Protection Agency, *Health Effects Assessment Summary Tables*, Annual FY-1991, January 1991.

18. Personal communication with A. Wolbarst, U. S. Environmental Protection Agency, Office of Radiation Programs, Washington, D. C., February 21, 1992.

19. U. S. Environmental Protection Agency, *National Oil and Hazardous Substances Pollution Contingency Plan*, 40 CFR 300, 56 FR 5605, February 11, 1991.

APPENDIX A

PIT 9

RESIDUAL RISK ASSESSMENT

INDUSTRIAL SCENARIO (INSTITUTIONAL CONTROL PERIOD, PIT 9 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

INGESTION OF SOIL

RADIONUCLIDE	Ci/g	CONC. pCi/G	IR G/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	0.05	250	25	2.80E-10	8.75E-08	0.00E+00
PU-239	0.00E+00	0.00E+00	0.05	250	25	3.10E-10	9.69E-08	0.00E+00
PU-240	0.00E+00	0.00E+00	0.05	250	25	3.10E-10	9.69E-08	0.00E+00
PU-242	0.00E+00	0.00E+00	0.05	250	25	3.00E-10	9.38E-08	0.00E+00
AM-241	0.00E+00	0.00E+00	0.05	250	25	3.10E-10	9.69E-08	0.00E+00
TOTAL								0.00E+00

INHALATION OF PARTICULATES

RADIONUCLIDE	Ci/g	CONC. pCi/M3	IR M3/D	EF D/Y	ED YRS	INH. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	20	250	25	4.20E-08	5.25E-03	0.00E+00
PU-239	0.00E+00	0.00E+00	20	250	25	4.10E-08	5.13E-03	0.00E+00
PU-240	0.00E+00	0.00E+00	20	250	25	4.10E-08	5.13E-03	0.00E+00
PU-242	0.00E+00	0.00E+00	20	250	25	3.90E-08	4.88E-03	0.00E+00
AM-241	0.00E+00	0.00E+00	20	250	25	4.00E-08	5.00E-03	0.00E+00
TOTAL								0.00E+00

INGESTION OF DRINKING WATER

RADIONUCLIDE	Ci/g	CONC. pCi/L	IR L/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	1	250	25	2.80E-10	1.75E-06	0.00E+00
PU-239	0.00E+00	0.00E+00	1	250	25	3.10E-10	1.94E-06	0.00E+00
PU-240	0.00E+00	0.00E+00	1	250	25	3.10E-10	1.94E-06	0.00E+00
PU-242	0.00E+00	0.00E+00	1	250	25	3.00E-10	1.88E-06	0.00E+00
AM-241	0.00E+00	0.00E+00	1	250	25	3.10E-10	1.94E-06	0.00E+00
TOTAL								0.00E+00

EXTERNAL EXPOSURE

RADIONUCLIDE	Ci/g	CONC. pCi/G	SOIL DEPTH, M	S. DENSITY G/M3	ED YRS	EF D/Y	EXT. SF Y/(pCi/M2)-1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	6.10E-14	1.57E-07	0.00E+00
PU-239	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	2.60E-14	6.68E-08	0.00E+00
PU-240	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	5.90E-14	1.52E-07	0.00E+00
PU-242	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	4.90E-14	1.26E-07	0.00E+00
AM-241	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	1.60E-12	4.11E-06	0.00E+00
TOTAL									0.00E+00

PIT 9

RESIDUAL RISK ASSESSMENT

INDUSTRIAL SCENARIO (INSTITUTIONAL CONTROL PERIOD, WAG-7 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

INGESTION OF SOIL

RADIONUCLIDE	Ci/g	CONC. pCi/G	IR G/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	0.05	250	25	2.80E-10	8.75E-08	0.00E+00
PU-239	0.00E+00	0.00E+00	0.05	250	25	3.10E-10	9.69E-08	0.00E+00
PU-240	0.00E+00	0.00E+00	0.05	250	25	3.10E-10	9.69E-08	0.00E+00
PU-242	0.00E+00	0.00E+00	0.05	250	25	3.00E-10	9.38E-08	0.00E+00
AM-241	0.00E+00	0.00E+00	0.05	250	25	3.10E-10	9.69E-08	0.00E+00
TOTAL								0.00E+00

INHALATION OF PARTICULATES

RADIONUCLIDE	Ci/g	CONC. pCi/M3	IR M3/D	EF D/Y	ED YRS	INH. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	20	250	25	4.20E-08	5.25E-03	0.00E+00
PU-239	0.00E+00	0.00E+00	20	250	25	4.10E-08	5.13E-03	0.00E+00
PU-240	0.00E+00	0.00E+00	20	250	25	4.10E-08	5.13E-03	0.00E+00
PU-242	0.00E+00	0.00E+00	20	250	25	3.90E-08	4.88E-03	0.00E+00
AM-241	0.00E+00	0.00E+00	20	250	25	4.00E-08	5.00E-03	0.00E+00
TOTAL								0.00E+00

INGESTION OF DRINKING WATER

RADIONUCLIDE	Ci/g	CONC. pCi/L	IR L/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	1	250	25	2.80E-10	1.75E-06	0.00E+00
PU-239	0.00E+00	0.00E+00	1	250	25	3.10E-10	1.94E-06	0.00E+00
PU-240	0.00E+00	0.00E+00	1	250	25	3.10E-10	1.94E-06	0.00E+00
PU-242	0.00E+00	0.00E+00	1	250	25	3.00E-10	1.88E-06	0.00E+00
AM-241	0.00E+00	0.00E+00	1	250	25	3.10E-10	1.94E-06	0.00E+00
TOTAL								0.00E+00

EXTERNAL EXPOSURE

RADIONUCLIDE	Ci/g	CONC. pCi/G	SOIL DEPTH, M	S. DENSITY G/M3	ED YRS	EF D/Y	EXT. SF Y/(pCi/M2)-1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	6.10E-14	1.57E-07	0.00E+00
PU-239	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	2.60E-14	6.68E-08	0.00E+00
PU-240	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	5.90E-14	1.52E-07	0.00E+00
PU-242	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	4.90E-14	1.26E-07	0.00E+00
AM-241	0.00E+00	0.00E+00	0.1	1.50E+06	25	250	1.60E-12	4.11E-06	0.00E+00
TOTAL									0.00E+(

PIT 9

RESIDUAL RISK ASSESSMENT

RESIDENTIAL SCENARIO (POST-INSTITUTIONAL CONTROL PERIOD, PIT 9 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

INGESTION OF SOIL

EXPOSURE	IR	EF	ED	SOIL INGESTION
	G/D	D/Y	YRS	G
CHILD (0-6)	0.2	350	6	4.20E+02
ADULT	0.1	350	24	8.40E+02
TOTAL EXPOSURE				1.26E+03

RAD.		CONC.	TOTAL INGESTION	ING. SF	UNIT RISK	CANCER RISK
	Ci/g	pCi/G	G	pCi -1	pCi/G -1	
PU-238	1.27E-19	1.27E-07	1.26E+03	2.80E-10	3.53E-07	4.48E-14
PU-239	1.79E-15	1.79E-03	1.26E+03	3.10E-10	3.91E-07	6.99E-10
PU-240	3.87E-16	3.87E-04	1.26E+03	3.10E-10	3.91E-07	1.51E-10
PU-242	1.98E-20	1.98E-08	1.26E+03	3.00E-10	3.78E-07	7.48E-15
AM-241	1.41E-14	1.41E-02	1.26E+03	3.10E-10	3.91E-07	5.51E-09
TOTAL						6.36E-09

INHALATION OF PARTICULATES

RAD.	CONC.	CONC.	IR	EF	ED	INH. SF	UNIT RISK	CANCER RISK
	Ci/M3	pCi/M3	M3/D	D/Y	YRS	pCi -1	pCi/m3 -1	
PU-238	5.31E-24	5.31E-12	20	350	30	4.20E-08	8.82E-03	4.68E-14
PU-239	7.53E-20	7.53E-08	20	350	30	4.10E-08	8.61E-03	6.48E-10
PU-240	1.62E-20	1.62E-08	20	350	30	4.10E-08	8.61E-03	1.39E-10
PU-242	8.33E-25	8.33E-13	20	350	30	3.90E-08	8.19E-03	6.82E-15
AM-241	5.93E-19	5.93E-07	20	350	30	4.00E-08	8.40E-03	4.98E-09
TOTAL								5.77E-09

PIT 9

RESIDUAL RISK ASSESSMENT

RESIDENTIAL SCENARIO (POST-INSTITUTIONAL CONTROL PERIOD, PIT 9 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

INGESTION OF DRINKING WATER

RAD.	Ci/g	CONC. pCi/L	IR L/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	1.27E-19	0.00E+00	2	350	30	2.80E-10	5.88E-06	0.00E+00
PU-239	1.79E-15	0.00E+00	2	350	30	3.10E-10	6.51E-06	0.00E+00
PU-240	3.87E-16	0.00E+00	2	350	30	3.10E-10	6.51E-06	0.00E+00
PU-242	1.98E-20	0.00E+00	2	350	30	3.00E-10	6.30E-06	0.00E+00
AM-241	1.41E-14	0.00E+00	2	350	30	3.10E-10	6.51E-06	0.00E+00
TOTAL								0.00E+00

INGESTION OF FOOD CROPS

RAD.	Ci/g	WATER CONC. pCi/L	Kd L/G	SOIL CONC. pCi/G	TOTAL SOIL CONC. pCi/G	Bv	CONC. VEG. pCi/G
PU-238	1.27E-19	0.00E+00	0.00E+00	1.27E-07	1.27E-07	4.50E-04	5.72E-11
PU-239	1.79E-15	0.00E+00	0.00E+00	1.79E-03	1.79E-03	4.50E-04	8.06E-07
PU-240	3.87E-16	0.00E+00	0.00E+00	3.87E-04	3.87E-04	4.50E-04	1.74E-07
PU-242	1.98E-20	0.00E+00	0.00E+00	1.98E-08	1.98E-08	4.50E-04	8.91E-12
AM-241	1.41E-14	0.00E+00	0.00E+00	1.41E-02	1.41E-02	5.50E-03	7.76E-05

RAD.	CONC. VEG. pCi/G	IR G/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	5.72E-11	8.62	350	30	2.80E-10	2.53E-05	1.45E-15
PU-239	8.06E-07	8.62	350	30	3.10E-10	2.81E-05	2.26E-11
PU-240	1.74E-07	8.62	350	30	3.10E-10	2.81E-05	4.89E-12
PU-242	8.91E-12	8.62	350	30	3.00E-10	2.72E-05	2.42E-16
AM-241	7.76E-05	8.62	350	30	3.10E-10	2.81E-05	2.18E-09
TOTAL							2.20E-09

PIT 9

RESIDUAL RISK ASSESSMENT

RESIDENTIAL SCENARIO (POST-INSTITUTIONAL CONTROL PERIOD, PIT 9 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

EXTERNAL EXPOSURE

RAD.	Ci/g	CONC. pCi/G	SOIL DEPTH, M	S. DENSITY G/M3	ED YRS	EF D/Y	EXT. SF Y/(pCi/M2) -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	1.27E-19	1.27E-07	0.1	1.50E+06	30	350	6.10E-14	2.63E-07	3.34E-14
PU-239	1.79E-15	1.79E-03	0.1	1.50E+06	30	350	2.60E-14	1.12E-07	2.01E-10
PU-240	3.87E-16	3.87E-04	0.1	1.50E+06	30	350	5.90E-14	2.55E-07	9.85E-11
PU-242	1.98E-20	1.98E-08	0.1	1.50E+06	30	350	4.90E-14	2.11E-07	4.19E-15
AM-241	1.41E-14	1.41E-02	0.1	1.50E+06	30	350	1.60E-12	6.90E-06	9.73E-08
TOTAL									9.76E-08

PIT 9

RESIDUAL RISK ASSESSMENT

RESIDENTIAL SCENARIO (POST-INSTITUTIONAL CONTROL PERIOD, WAG-7 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

INGESTION OF SOIL

EXPOSURE	IR G/D	EF D/Y	ED YRS	SOIL INGESTION G
CHILD (0-6)	0.2	350	6	4.20E+02
ADULT	0.1	350	24	8.40E+02
TOTAL EXPOSURE				1.26E+03

RAD.	Ci/g	CONC. pCi/G	TOTAL INGESTION G	ING. SF pCi -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	4.38E-23	4.38E-11	1.26E+03	2.80E-10	3.53E-07	1.55E-17
PU-239	6.20E-19	6.20E-07	1.26E+03	3.10E-10	3.91E-07	2.42E-13
PU-240	1.34E-19	1.34E-07	1.26E+03	3.10E-10	3.91E-07	5.23E-14
PU-242	6.86E-24	6.86E-12	1.26E+03	3.00E-10	3.78E-07	2.59E-18
AM-241	4.88E-18	4.88E-06	1.26E+03	3.10E-10	3.91E-07	1.91E-12
TOTAL						2.20E-12

INHALATION OF PARTICULATES

RAD.	CONC. Ci/M3	CONC. pCi/M3	IR M3/D	EF D/Y	ED YRS	INH. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	5.82E-26	5.82E-14	20	350	30	4.20E-08	8.82E-03	5.13E-16
PU-239	8.24E-22	8.24E-10	20	350	30	4.10E-08	8.61E-03	7.09E-12
PU-240	1.78E-22	1.78E-10	20	350	30	4.10E-08	8.61E-03	1.53E-12
PU-242	9.12E-27	9.12E-15	20	350	30	3.90E-08	8.19E-03	7.47E-17
AM-241	6.49E-21	6.49E-09	20	350	30	4.00E-08	8.40E-03	5.45E-11
TOTAL								6.31E-11

PIT 9

RESIDUAL RISK ASSESSMENT

RESIDENTIAL SCENARIO (POST-INSTITUTIONAL CONTROL PERIOD, WAG-7 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

INGESTION OF DRINKING WATER

RAD.	Ci/g	CONC. pCi/L	IR L/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	4.38E-23	0.00E+00	2	350	30	2.80E-10	5.88E-06	0.00E+00
PU-239	6.20E-19	0.00E+00	2	350	30	3.10E-10	6.51E-06	0.00E+00
PU-240	1.34E-19	0.00E+00	2	350	30	3.10E-10	6.51E-06	0.00E+00
PU-242	6.86E-24	0.00E+00	2	350	30	3.00E-10	6.30E-06	0.00E+00
AM-241	4.88E-18	0.00E+00	2	350	30	3.10E-10	6.51E-06	0.00E+00
TOTAL								0.00E+00

INGESTION OF FOOD CROPS

RAD.	Ci/g	WATER CONC. pCi/L	Kd L/G	SOIL CONC. pCi/G	TOTAL SOIL CONC. pCi/G	Bv	CONC. VEG. pCi/G
PU-238	4.38E-23	0.00E+00	0.00E+00	4.38E-11	4.38E-11	4.50E-04	1.97E-14
PU-239	6.20E-19	0.00E+00	0.00E+00	6.20E-07	6.20E-07	4.50E-04	2.79E-10
PU-240	1.34E-19	0.00E+00	0.00E+00	1.34E-07	1.34E-07	4.50E-04	6.03E-11
PU-242	6.86E-24	0.00E+00	0.00E+00	6.86E-12	6.86E-12	4.50E-04	3.09E-15
AM-241	4.88E-18	0.00E+00	0.00E+00	4.88E-06	4.88E-06	5.50E-03	2.68E-08

RAD.	CONC. VEG. pCi/G	IR G/D	EF D/Y	ED YRS	ING. SF pCi -1	UNIT RISK pCi/m3 -1	CANCER RISK
PU-238	1.97E-14	8.62	350	30	2.80E-10	2.53E-05	5.00E-19
PU-239	2.79E-10	8.62	350	30	3.10E-10	2.81E-05	7.83E-15
PU-240	6.03E-11	8.62	350	30	3.10E-10	2.81E-05	1.69E-15
PU-242	3.09E-15	8.62	350	30	3.00E-10	2.72E-05	8.38E-20
AM-241	2.68E-08	8.62	350	30	3.10E-10	2.81E-05	7.53E-13
TOTAL							7.63E-13

PIT 9

RESIDUAL RISK ASSESSMENT

RESIDENTIAL SCENARIO (POST-INSTITUTIONAL CONTROL PERIOD, WAG-7 BOUNDARY)

CARCINOGENIC EFFECTS, TRANSURANIC ELEMENTS (10 nCi/G)

EXTERNAL EXPOSURE

RAD.	Ci/g	CONC. pCi/G	SOIL DEPTH, M	S. DENSITY G/M3	ED YRS	EF D/Y	EXT. SF Y/(pCi/M2) -1	UNIT RISK pCi/G -1	CANCER RISK
PU-238	4.38E-23	4.38E-11	0.1	1.50E+06	30	350	6.10E-14	2.63E-07	1.15E-17
PU-239	6.20E-19	6.20E-07	0.1	1.50E+06	30	350	2.60E-14	1.12E-07	6.96E-14
PU-240	1.34E-19	1.34E-07	0.1	1.50E+06	30	350	5.90E-14	2.55E-07	3.41E-14
PU-242	6.86E-24	6.86E-12	0.1	1.50E+06	30	350	4.90E-14	2.11E-07	1.45E-18
AM-241	4.88E-18	4.88E-06	0.1	1.50E+06	30	350	1.60E-12	6.90E-06	3.37E-11
TOTAL									3.38E-11